PRELIMINARY REPORT
Hurricane Marco
16-24 November 1996

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Hurricane Marco drifted aimlessly over the western Caribbean Sea for about a week threatening several land areas but never making landfall.

a. Synoptic History

A cold front moved into the northwestern Caribbean on 9 November, followed by an abnormally strong high pressure system which dominated the eastern United States. The front became nearly stationary and interacted with a series of westward moving tropical waves. The Intertropical Convergence Zone (ITCZ) became active in the southwestern Caribbean as monsoonal southwesterly flow from the eastern Pacific reached the area. As early as 13 November, surface analysis showed a weak low pressure area just north of Colombia and, by the next day, there was a well-defined but broad low-level circulation between Jamaica and Honduras. At that time, the system did not meet the criteria for tropical depression status because the convection was not concentrated nor organized near a center of circulation. In fact, there were several smaller centers of circulation embedded within a much larger system. The broad area of low pressure drifted northward for a couple of days, and in combination with a high pressure system over the United States, produced gale force winds over Florida, Cuba, the Bahamas and the Gulf of Mexico.

The convection gradually became organized south of Jamaica and a post-analysis of the surface and reconnaissance aircraft data indicates that the system became a tropical depression at 1800 UTC November 16. The poorly-defined tropical depression moved generally southward and encountered a much better upper-level environment for strengthening. It became a tropical storm at 0600 UTC 19 November and then moved on a slow east-northeast track. Marco briefly reached hurricane status at 0600 UTC 20 November with maximum winds of 65 knots and a minimum pressure of 983 mb. Thereafter, Marco was hit by strong upper-level westerlies and

weakened rapidly to a tropical depression at 1800 UTC 23 November. It was then located just to the southeast of Jamaica.

Once a middle-level ridge rebuilt over the Bahamas and Florida, Marco turned toward the west and west-northwest and regained tropical storm strength. The tropical cyclone was south of the western tip of Cuba when it interacted with a cold front and dissipated by 1800 UTC 26 November. The remnants of Marco drifted southward and produced heavy rains over Honduras and Belize.

Marco was characterized by its numerous intensity fluctuations. For several consecutive days, Marco became disorganized during the afternoon when the low-level center was practically exposed and there was an increase in the central pressure. This was followed by a significant redevelopment of the convection and a drop in pressure during the nights and early mornings. These fluctuations could be attributed to the interaction of Marco with a series of fast moving shortwave troughs and ridges observed on water vapor imagery. These features increased and relaxed the shear while moving through the area.

Marco's track is shown in Fig. 1. Table 1 is a listing, at six-hour intervals, of the "best-track" position, estimated minimum central pressure and maximum 1-minute surface wind speed.

b. Meteorological Statistics

The best track pressure and wind curves as a function of time are shown in Figures 2 and 3 and are based on reconnaissance and surface observations, satellite intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) of the Tropical Prediction Center. It also includes estimates from the Synoptic Analysis Branch (SAB) and the Air Force Global Weather Center (AFGWC).

Marco was upgraded to a hurricane based on a 63-knot 1-min sustained wind reported by a U.S. Navy ship. Shortly thereafter. A reconnaissance plane reported a minimum pressure of 983 mb and 1-sec wind of 89 knots. This was a significant pressure drop of 11 mb in 1 h and 40 minutes. During that flight, the crew reported a volatile center structure with severe turbulence, extreme rainfall and hail. Satellite images showed very cold convective tops at that time. During the early morning flight of 22 November, the reconnaissance plane observed another pressure drop from 996 to

985mb in about 2 hours, and a 5 n mi diameter eye. The vessel PFAS reported sustained winds of 56 knots and a pressure of 1007.5 mb at 1200 UTC 25 November. This observation was used to operationally upgrade Marco to a tropical storm for the second time.

Table 2 contains selected surface observations and ships reporting 34-knot winds or higher.

c. Casualty and Damage Statistics

Marco never hit land but its large circulation brought heavy rains to Central America and Hispaniola. These rains produced floods and mud slides causing at least eight deaths. The interaction of Marco during its developing stage with a strong high over the U.S. resulted in gale force winds which produced beach erosion along the east coast of Florida.

d. Forecast and Warning Critique

Since Marco moved very slowly watches or warnings were in place for Jamaica for several days. Table 3 summarizes the watches and warnings associated with Marco. For about eight consecutive days before Marco developed, the MRF consistently forecast the formation of a tropical cyclone in the western Caribbean, (see Fig. 3). This formation was also suggested by both the UKMET and the EMCWF global models a couple of days later.

The official forecast errors ranged from 44 n mi at 12 hours to 274 n mi at 72 hours. The 10-year average errors are 50 and 296 n mi respectively. The lowest errors at 72 hours (better than the official) were produced by the UKMI, BAMS and BAMM and the largest error was produced by VBRI. The GFDI (an interpolated version of the GFDL model)error was 349 n mi at 72 hours. Because Marco was a shallow tropical cyclone for a long period, it was steered by the middle-to low-level tropospheric flow. This probably contributed to such a low track 72-hour errors produced by the BAMM and BAMS models.

Figure Captions:

Fig. 1. Best track positions for Hurricane Marco, 16 - 26 November 1996.

Fig. 2. Best track one-minute surface wind speed curve for Hurricane Marco.

Fig. 3. Best track minimum central pressure curve for Hurricane Marco.

Fig. 4 Output of the MRF model run at 0000 UTC 8 November, valid for 1200 UTC 17 November. Dot represents Marco's position on that date.

Table 1. Preliminary best track, Hurricane Marco, 16-24 November, 1996.

Date/time (UTC)	Position Lat. (°N)	Position Lon.(°W)	Pressure	Wind speed(kt)	Stage
13/1200	10.5	77.5	1009	20	Low
1800	11.3	78.0	1009	20	
14/0000	12.0	78.5	1009	20	
0600	12.8	78.9	1009	20	
1200	13.5	79.0	1008	20	
1800	14.0	79.0	1008	20	
15/0000	14.3	79.0	1008	20	
0600	14.7	79.0	1008	20	
1200	15.0	79.0	1008	20	
1800	15.5	79.0	1008	20	
16/0000	15.8	79.0	1008	20	
0600	16.2	79.0	1008	20	
1200	16.5	79.0	1007	25	
1800	17.0	79.0	1007	30	TD
17/0000	16.8	79.8	1007	30	
0600	16.3	80.5	1007	30	
1200	15.8	80.8	1007	30	
1800	15.0	81.0	1006	30	
18/0000	14.9	81.0	1006	30	
0600	14.7	81.0	1005	30	
1200	14.6	81.0	1004	30	
1800	14.5	81.0	1003	30	
19/0000	14.2	81.0	1001	30	
0600	13.8	80.9	998	35	TS
1200	13.5	80.7	997	45	
1800	13.5	80.2	995	55	
20/0000	13.8	79.5	990	60	
0600	13.8	78.5	983	65	H
1200	14.2	77.8	989	65	
1800	14.6	77.4	1000	45	TS
21/0000	14.9	77.1	1000	45	
0600	15.1	76.8	995	45	

1200	15.3	76.6	993	50	
1800	15.6	76.5	995	50	
22/0000	15.8	76.3	992	55	
0600	15.9	76.0	985	55	
1200	15.9	75.4	987	60	
180Q	15.9	75.0	995	50	
23/0000	16.0	74.7	995	45	
0600	15.9	74.5	995	35	
1200	15.7	74.5	995	35	
1800	15.6	74.8	1000	30	TD
24/0000	15.8	76.0	1002	30	
0600	15.9	77.0	1003	30	
1200	16.0	78.0	1003	35	TS
1800	16.0	78.9	1003	35	
25/0000	16.7	80.2	1002	45	
0600	17.5	81.5	1002	50	
1200	18.3	82.6	1001	55	
1800	19.2	83.5	1009	45	
26/0000	19.7	84.0	1009	40	
0600	20.1	84.4	1010	35	
1200	20.1	84.3	1010	30	TD
1800	19.6	84.8	1010	25	D
20/0600[1]	**13.8**	**78.5**	**983**	**65**	

[1] minimum pressure
TD tropical depression
TS tropical storm
H hurricane
D dissipating

Table 2. Ship reports of 34 knots or higher wind speed, associated with Hurricane Marco, November 1996.

date/time (UTC)	ship name	latitude °N	longitude °W	wind dir/speed knots	pressure (mb)
19/1500	***PFRO***	14.5	79.6	100/34	1006.1
19/1800	*PFRO*	15.4	78.5	120/36	1006.2
19/188	***PEEX***	10.3	81.8	280/35	1005.8
20/0600	***U.S. Navy***			63	998.0
21/2100	***C6JP***	13.5	76.0	230/35	1002.2
22/0000	***SGLU***	17.6	74.5	120/34	1009.8
25/1200	*PFAS*	18.6	82.6	030/56	1007.5
25/1800	***PDJS***	20.4	82.9	090/47	1013.2

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20/0600	*U.S. Navy*			63	998.0
25/1200	*PFAS*	18.6	82.6	030/56	1007.5

To be completed.

Table 3. Watch and warning summary, Hurricane Marco, November 1996.

Date/time (UTC)	Action	Location
19/1500	tropical storm watch issued	Jamaica
20/1500	hurricane warning issued	Jamaica
20/1500	hurricane watch issued	Cuba from Camaguey eastward and for Haiti
20/2100	hurricane warning replaced by a tropical storm warning	Jamaica
20/2100	hurricane watch replaced by a tropical storm watch	Cuba from Camaguey eastward and Haiti
21/1500	tropical storm warning replaced by tropical storm watch	Jamaica
21/1500	tropical storm watch discontinued	Cuba and Haiti
22/1500	tropical storm watch discontinued	Jamaica
25/1500	tropical storm warning issued	Isle of Youth and Pinar del Rio province, Cuba
26/1500	tropical storm watch discontinued	Cuba

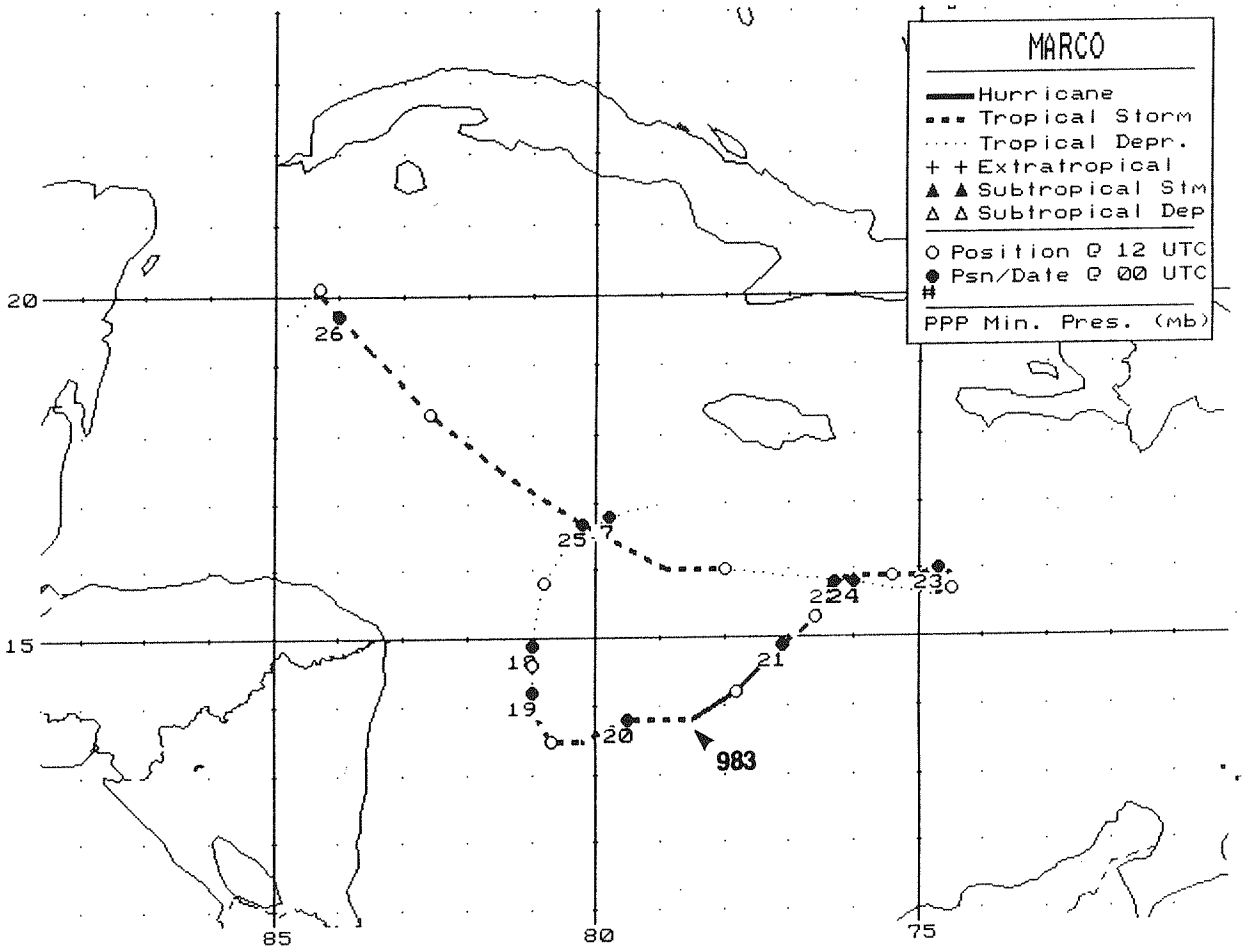

Fig. 1. Best track positions for Hurricane Marco, 16 - 26 November 1996.

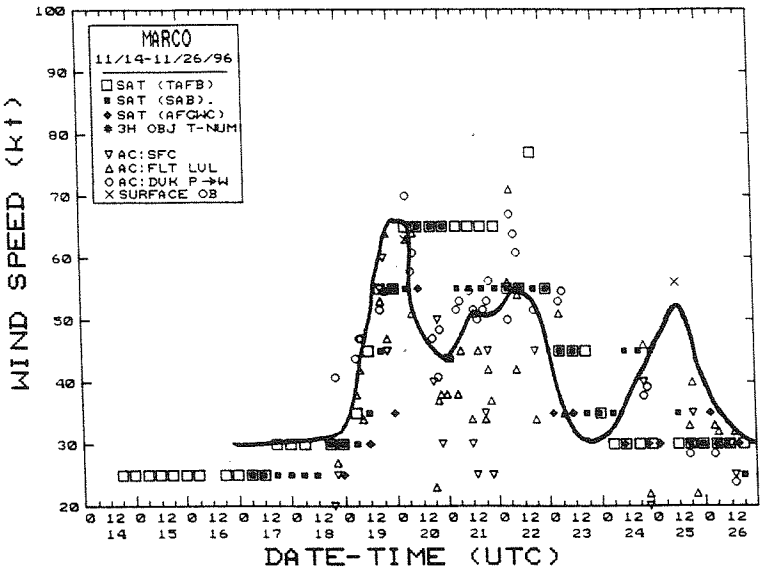

Fig. 2. Best track one-minute surface wind speed curve for Hurricane Marco.

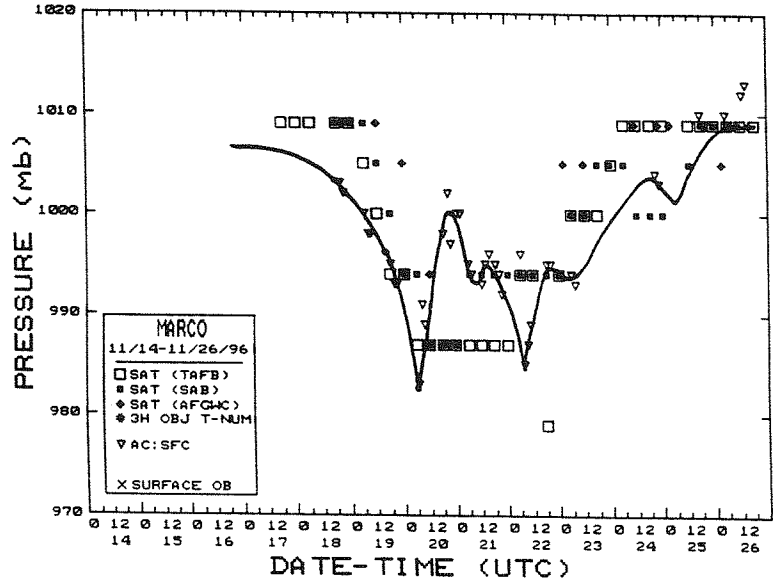

Fig. 3. Best track minimum central pressure curve for Hurricane Marco.

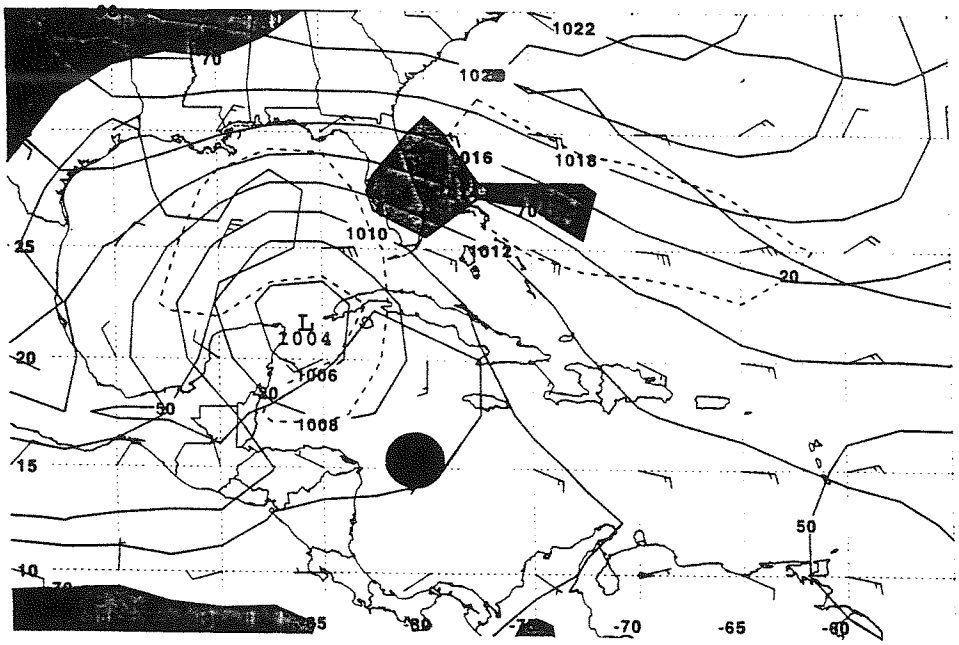

Fig. 4 Output of the MRF model run at 0000 UTC 8 November, valid for 1200 UTC 17 November.